

Global burden of disease

Le poids de la morbidité dans le monde

Assessing the health situation in populations has traditionally been carried out on the basis of mortality data, and where available, on the prevalence and/or incidence of disease. A new approach to quantifying the burden of disease has been developed which simultaneously considers both premature death as well as the non-fatal health consequences of disease and injury. The burden of disease approach is based on an incidence perspective and provides an estimate of the number of years of life lost due to premature death (in 1990), and the number of years of life lived with a disability arising from new cases of disease or injury in 1990. These two components constitute the total number of disability-adjusted life years (DALYs) due to disease or injury incurred in 1990. The results of this approach were first utilized in the World development report 1993: investing in health.

The following four articles present, for the first time, details about the methods, assumptions and findings of the global burden of disease methodology. The first article summarizes the principles and properties of the DALY measure. The detailed set of age, sex, cause-specific mortality rates used to estimate the years of life lost from premature death are presented in the second paper. The third article gives details about the estimated years of life lived with a disability, reflecting the likelihood of progressing from disease incidence to disability, the duration of disability, and its severity. The fourth paper provides a summary of the DALYs arising from both components and shows that the results are relatively insensitive to assumptions about parameter values used in the calculation. This article also provides an overview of how the method might be applied to assist countries with their own health situation assessment.

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L'évaluation de l'état de santé des populations s'appuie classiquement sur les données de la mortalité et, lorsqu'elles sont disponibles, sur la prévalence et/ou l'incidence de la maladie. Une nouvelle méthode de mesure quantitative du poids de la morbidité a été mise au point, qui tient compte simultanément du décès prématuré et des conséquences non fatales pour la santé de la maladie et du traumatisme. Cette méthode se place dans la perspective de l'incidence et fournit une estimation du nombre d'années de vie perdues à la suite d'un décès prématuré (en 1990) et du nombre d'années de vie vécues avec une incapacité à la suite des nouveaux cas de maladie ou de traumatisme apparus en 1990. Ces deux éléments entrent dans la composition du nombre total de DALY (disability-adjusted life years: années de vie ajustées sur l'incapacité) dues à une maladie ou à un traumatisme survenus en 1990. Les résultats d'une telle approche ont été utilisés pour la première fois dans le Rapport sur le développement dans le monde 1993: investir dans la santé.

Les quatre articles qui suivent exposent pour la première fois les détails concernant la procédure suivie, les hypothèses, et les résultats de cette méthode de détermination du poids de la morbidité dans le monde. Le premier article résume les principes et les propriétés des DALY. Les taux de mortalité par âge, par sexe et par cause, utilisés pour estimer les années de vie perdues par décès prématuré, sont précisément exposés dans le deuxième article. Le troisième article donne des détails sur le nombre estimé d'années vécues en incapacité, reflétant la probabilité d'évolution depuis la survenue de la maladie jusqu'à l'incapacité, la durée de l'incapacité et sa gravité. Le quatrième article de cette série donne un résumé des DALY imputables à ces deux éléments et montre que les résultats varient relativement peu avec les hypothèses sur les valeurs des paramètres utilisés dans le calcul. Cet article donne également un aperçu de l'utilisation possible de cette méthode pour aider les pays à évaluer l'état de santé de leur population.

Quantifying the burden of disease: the technical basis for disability-adjusted life years

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Detailed assumptions used in constructing a new indicator of the burden of disease, the disability-adjusted life year (DALY), are presented. Four key social choices in any indicator of the burden of disease are carefully reviewed. First, the advantages and disadvantages of various methods of calculating the duration of life lost due to a death at each age are discussed. DALYs use a standard expected-life lost based on model life-table West Level 26. Second, the value of time lived at different ages is captured in DALYs using an exponential function which reflects the dependence of the young and the elderly on adults. Third, the time lived with a disability is made comparable with the time lost due to premature mortality by defining six classes of disability severity. Assigned to each class is a severity weight between 0 and 1. Finally, a three percent discount rate is used in the calculation of DALYs. The formula for calculating DALYs based on these assumptions is provided.

Introduction

This paper provides the technical basis for a new measure of the burden of disease: the disability-adjusted life year (DALY). It is one of four papers in this issue of the *Bulletin of the World Health Organization* on the Global Burden of Disease study (1-3); this first one details the conceptual basis for the indicator, the second examines the empirical basis for measuring time lost due to premature mortality by cause, the third describes the time lived with a disability by cause, and the fourth presents summary results and a sensitivity analysis. In this article, the rationale for measuring the burden of disease, the need for a single indicator of burden, some general concepts used in the design of an indicator of the burden of disease, a series of specific value choices, and some computational aspects are analysed in turn.

Why measure the burden of disease?

The intended use of an indicator of the burden of disease is critical to its design. At least four objectives are important.

- to aid in setting health service (both curative and preventive) priorities;
- to aid in setting health research priorities;
- to aid in identifying disadvantaged groups and targeting of health interventions;
- to provide a comparable measure of output for intervention, programme and sector evaluation and planning.

Not everyone appreciates the ethical dimension of health status indicators (4). Nevertheless, the first two objectives listed for measuring the burden of disease could influence the allocation of resources among individuals, clearly establishing an ethical dimension to the construction of an indicator of the burden of disease.

Single and multiple indicators of disease burden

Since Sullivan's proposal of a composite index of health status incorporating information on morbidity and mortality (5, 6), there has been extensive debate on the utility of such single indicators of health status (7). For our purposes, this debate on the value of constructing single indicators can be reduced to a basic choice between explicit and implicit valuations. Decision-makers who allocate resources to competing health programmes must choose between the relative importance of different health outcomes such as mortality reduction or disability prevention. Because money is unidimensional, the allocation of resources between programmes defines a set of relative weights for different health outcomes. The only exception to this is in a completely free market for health care where such decisions between competing health programmes are not made by a central authority but by individuals, one health problem at a time. Even in the USA, competitive resource allocation choices are still made for at least subsegments of the population such as Medicaid, Medicare and Veterans Administration beneficiaries. If the process of choosing relative weights of different types of health outcomes is left entirely to the political or bureaucratic process there is a high probability that similar health outcomes may be weighted inconsistently, perhaps

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Reprint No. 5494

reflecting the political voices of different constituencies. More importantly, there may be no open discussion or debate on key value choices or differential weightings. The wide variation in the implied value of saving a life in public safety legislation is but one example (8).

Alternatively, we can explicitly choose a set of relative values for different health outcomes and construct a single indicator of health. The black box of the decision-maker's relative values is then opened for public scrutiny and influence. Both this paper and the others in this series on the burden of disease are predicated on the desirability of making implicit values explicit. Development of a single indicator of the burden of disease for use in planning and evaluating the health sector is described below.

Some general concepts

This paper is not intended to present a new paradigm for measuring health, nor to firmly identify one intellectual tradition such as utilitarianism, human rights, or Rawls' theory of justice (9) as the basis for the social preferences incorporated into DALYs. Rather, the majority of the paper is devoted to a discussion of several types of social preferences which must be incorporated into any indicator of health status. In order to derive a usable indicator, a particular stand is also taken on each of the social values described. The philosophical basis for this position will not be argued in detail. For the interested reader, an indicator very similar to DALYs has been developed based on Rawls' device of the "original position". That is a type of thought experiment where a group of individuals, ignorant of each other's social position, age, sex and other characteristics, are asked to choose the values and institutions to govern society. An "original position" could be invoked for a more specific task such as choosing the values to be incorporated in a health indicator.^{a, b} Further philosophical treatment is excluded here.

However, four general concepts in the development of DALYs, which have enjoyed wide consensus with the groups involved in the study, are presented. These concepts are not derived from one particular conception of the good and may in fact be based on mutually inconsistent ethical frameworks. Nevertheless, the purpose of this paper is to explain

the technical assumptions underlying DALYs and not to propose a unified ethical framework for all health sector analysis. In our discussion of the details of various social preferences incorporated into the indicator, we make reference to these concepts. The reader who finds these concepts intuitively plausible may feel comfortable with DALYs as a measurement tool.

(1) *To the extent possible, any health outcome that represents a loss of welfare should be included in an indicator of health status*

Any health outcome that affects social welfare should in some way be reflected in the indicator of the burden of disease. In other words, if society would be willing to devote some resources to avert or treat a health outcome, that outcome should be included in the total estimated burden. As will be seen later, this is at odds with one major stream of work on the measurement of disability which ignores all forms of disability below some thresholds of severity and duration. Note that by making reference to the concept of welfare we are not claiming that DALYs are the best measure of the health component of social welfare. Nor that maximizing DALYs gained from health interventions up to some cost per DALY would be consistent with an objective of maximizing social welfare, although this argument has been formally made (10). The link between health maximization, as measured by DALYs or any other measure, and welfare maximization would require another paper to adequately address the complexities of this issue.

(2) *The characteristics of the individual affected by a health outcome that should be considered in calculating the associated burden of disease should be restricted to age and sex*

Every health outcome such as the premature death of a 45-year-old man from a heart attack or permanent disability from blindness due to a road accident in a 19-year-old woman can be characterized by a set of variables. Some of these variables define the specific health outcome itself such as the etiology, type, severity or duration of the disability. Others are individual characteristics such as sex, age, income, educational attainment, religion, ethnicity, occupation, etc. In the most general terms, the task of constructing a burden of disease measure is to take an *n*-dimensional matrix of information on health outcomes and collapse this into a single number. To transform this complex array of information, what are the variables that should be included or indeed allowed to be considered? Some might argue that all

^a Murray CJL. *Mortality measurement and social justice*. Paper presented at the Annual Conference of the Institute of British Geographers, 5 January 1986, Reading, England.

^b Murray CJL. *The determinants of health improvement in developing countries. Case-studies of St. Lucia, Guyana, Paraguay, Kiribati, Swaziland and Bolivia*. Oxford University D. Phil. thesis, 1988.

the variables may be relevant and none should be excluded *a priori*. At the limit, this is a form of total relativism since every health outcome becomes unique and there is no meaning to an aggregate indicator.

Others might want to include variables that are unacceptable to the authors. The government of South Africa under apartheid implicitly put a higher relative weight on health outcomes in whites as compared to blacks. Nearly everyone would agree that attributes such as race, religion or political beliefs have no place in the construction of a health indicator. Some, however, might see a logic of including income or educational status such that the health of the wealthy counted more than the health of the poor. Estimations of the cost of disease (11, 12) use methods that value equivalent health outcomes in higher income groups as more costly than the same outcomes in the poor.

The set of variables that can be considered are restricted here to those defining the particular health outcome and individual characteristics that are general to all communities and households, namely age and sex. Daniels (13) has argued that differentiation by age should not be viewed as pitting the welfare of one age group against another, but rather as viewing an individual during different phases of the life-cycle. Variables defining subgroups such as income or education, which not all individuals or households can hope to belong to, are expressly excluded from consideration. This is a fundamental value choice founded on our notions of social justice. Some readers, with different values and conceptions of social justice, might conclude that other information should be included in assessing health status.

(3) *Treating like health outcomes as like*

We articulate a principle of treating like health outcomes as like. For example, the premature death of a 40-year-old woman should contribute equally to estimates of the global burden of disease irrespective of whether she lives in the slums of Bogota or a wealthy suburb of Boston. Treating like events equally also ensures comparability of the burden of disease across different communities and in the same community over a period of time. Community-specific characteristics such as local levels of mortality should not change the assumptions incorporated into the indicator design. The value of a person's health status is his or her own and does not depend on his or her neighbour's health status. A concrete example of this will be discussed in the section on the duration of time lost due to premature mortality. The approach presented means that occasionally we will sacrifice consistency with cost-effectiveness

measures but retain comparability of burden across communities and a plausible treatment of equity.

(4) *Time is the unit of measure for the burden of disease*

Many health indicators measure the occurrence of events such as disease incidence or death per unit time and others measure these events per unit population. The units of measure are specific to the entity studied such as infant deaths for the infant mortality rate or measles cases in the measles attack rate. For a composite health indicator, a more general unit of measure is required. The best candidate for a general unit of measure is time itself, denominated in years or days. Using time as the unit of measure also provides a simple and intuitive method to combine the time lived with a disability with the time lost due to premature mortality. Measuring health status using time is not a new idea; the concept of years of life lost from dying young has been in use for nearly 45 years (14). The development of time-based measures and the myriad modifications of this approach are explored more fully below.

Incidence versus prevalence perspectives

With time as the chosen unit of measure, the burden of disease could still be an incidence- or prevalence-based indicator. Time lost due to premature mortality is a function of death rates and the duration of life lost due to a death at each age. Because death rates are incidence rates, there is no obvious alternative for mortality to using an incidence approach. There are no calculated measures of the prevalence of the dead. In contrast, for disability both incidence and prevalence measures are in routine use. There are at least two ways of measuring the aggregate time lived with a disability. One method is to take point prevalence measures of disability, adjusting for seasonal variation if present, and estimate the total time lived with the disability as prevalence \times one year. The alternative is to measure the incidence of disabilities and the average duration of each disability. Incidence \times duration will then provide an estimate of the total time lived with the disability.

If the incidence of disabilities is constant over time and the population age-structure is also constant, then the prevalence and incidence approaches yield exactly the same total amount of time lived with a disability. For nearly all populations the age structure is not constant and for many diseases such as lung cancer, cervical cancer, stomach cancer, HIV infection, and leprosy the incidence is changing over time. For the Global Burden of Disease study, we have chosen to use an incidence perspective for three

reasons. First, with the method of calculating time lived with disabilities is more consistent with the method for calculating time lost due to premature mortality. Second, an incidence perspective is more sensitive to current epidemiological trend and will reflect the impact of health interventions more rapidly. The results of the Global Burden of Disease study, presented in Murray et al. (3) have also been calculated using a prevalence approach. These prevalence-based measures of the burden of disease will be published at a later date (15). Third, measuring the incidence or deriving it from prevalence data and information on case-fatality and remission rates imposes a level of internal consistency and discipline that would be missing if the prevalence data were used uncritically.

Specific value choices in designing an indicator of burden

In the following sections, we address in detail the four key social preferences or values that must be incorporated into an indicator of the burden of disease. These are: the duration of time lost due to a death at each age, the value of time lived at different ages, non-fatal health outcomes (converting time lived with a disability to be comparable with time lost due to premature mortality), and time preference.

The duration of time lost due to premature death

Since Dempsey (14) introduced the concept of measuring lost time due to mortality rather than crude or age-standardized death rates, a wide variety of methods for measuring years of life lost have been proposed (16–23). Because the same terms have been used to describe quite different measures of lost time, there is substantial confusion on the precise method used in any particular study.

At least four different methods of estimating the duration of time lost due to premature death are possible. The following terminology is introduced in an attempt to clarify the discussion and comparison of methods: potential years of life lost, period expected years of life lost, cohort expected years of life lost, and standard expected years of life lost. Each measure is defined and its advantages and disadvantages are reviewed. In the earliest literature on measuring years of life lost, there was also considerable debate about the 'zero mortality assumption' (17–19). Using this assumption, calculating the years of life lost due to a particular disease entails recalculating a life-table in the absence of mortality from that cause at any age. Thus the number of years of life lost due to a tuberculosis death at age 40 would be different

from a motor vehicle accident at age 40. Such methods violate the concept of treating like health outcomes identically and are not discussed further.

(1) *Potential years of life lost* are calculated by defining a potential limit to life and calculating the years lost due to each death as the potential limit minus the age at death. The formula for the number of years of potential life lost in a population is in notation:

$$\sum_{x=0}^{x=L} d_x (L-x)$$

where d_x is deaths at age x , and L is the potential limit to life. A wide range of potential limits to life have been in used in practice, ranging from 60 to 85 (16–18, 22–25). The choice of the upper limit is arbitrary and the arguments are made on statistical grounds. Dempsey (14) proposed that the limit to life be selected as life expectancy at birth for a given population. Romeder & McWhinnie (16) have argued that the potential years of life lost should be calculated based only on deaths over age 1 to avoid being too heavily affected by infant mortality. This is a strange argument which has little intuitive appeal. If the indicator is to be used in informing resource allocation decisions, we would not want to ignore infant deaths. Proponents of the potential years of life lost approach, point to its ease of calculation and the egalitarian treatment of all deaths at a given age as equally important in contributing to the estimated total. If the potential limit to life is chosen as close to life expectancy, the results for the younger age groups are not substantially different from those for expected years of life lost (discussed below). The major disadvantage is in the treatment of deaths in the older population. Deaths over the arbitrary potential limit to life, for example 65 as calculated by the Centers for Disease Control (CDC) in the USA, do not contribute to the estimated burden of disease. This runs counter to our first principle because society clearly does care about the health of these groups and expends substantial resources in all countries on their health care. Even in high mortality populations, societies do appear to care about the health of the population over 60 or 70.

(2) An alternative is to calculate the *period expected years of life lost* (17–19, 21), using the local expectation of life at each age as the estimate of the duration of life lost at each age. Period expected years of life lost has become the standard method of estimating years of life lost in many cost-effectiveness studies

(26, 27). This method is seen as a more 'realistic' estimate of the stream of life gained by averting a death, given competing risks of death in a particular population. More formally,

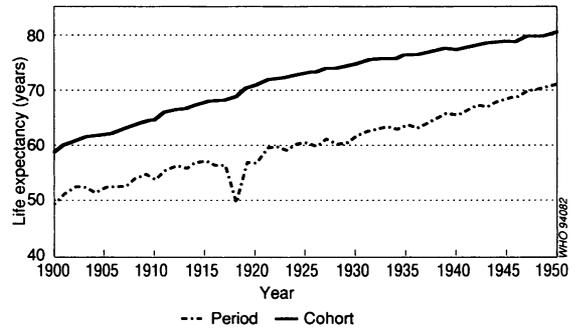
$$\sum_{x=0}^{x=l} d_x e_x$$

where l is the last age group and e_x is the expectation of life at each age. Because the expectation of life does not drop to zero at an arbitrary age, this method has the advantage of providing a more appealing estimate of the stream of lost life due to deaths in the older age groups. However, application of the period expectation method with locally different values of life expectancy would lead us to conclude that the death of a 40-year-old woman in Kigali contributes less to the global burden of disease than the death of a 40-year-old woman in Paris because the expectation of life at age 40 in Rwanda is lower than in France. Equivalent health outcomes would be a greater burden in richer communities than in poorer communities. As this runs counter to the principle of treating like events as like, this method is not used for estimating disability-adjusted life years.

The claim that period expected years of life lost are a more realistic estimate of the true duration of time lost due to premature mortality rests on three questionable assumptions. First, if a death is averted, that individual will then be exposed to the same mortality risks as the average individual in the population. In other words, the individual whose death is averted would not have a higher risk of subsequent death than the rest of the population. This may not be true for many chronic disabling conditions; likewise, because much mortality is concentrated in the chronically ill, averting a random death from injury may save more years than average expectation. For the population as a whole, the assumption of being exposed to the average mortality risk is reasonable. When evaluating specific interventions in a cost-effectiveness study, care must be taken to evaluate directly this question of interdependent mortality risks.

Second, period life expectancies are calculated based on the assumption that someone alive today will be exposed in the future to currently observed age-specific mortality rates at each age. Twentieth century mortality history demonstrates that this is a completely fallacious assumption, particularly in a population with moderate or high mortality (Fig. 1). Mortality has been declining at a steady pace throughout the last decades so that the life expectan-

Fig. 1. Period and cohort life expectancy at birth, 1900-1950, USA females.



cy of a cohort, the real expectation of life based on the mortality experience of a group over time, is much higher than the period life expectancy based on currently observed rates. Fig. 1 shows how the cohort life expectancy at birth for US females has been 10-15 years higher than period life expectancy from 1900 to 1950.

Third, if we conceive of the burden of disease as the gap between current conditions and some ideal, why would one choose current mortality patterns to define that ideal and the existing gap? Such a standard would also have to be changed each year as life expectancy increases, leading to paradoxical situations where improvements in life expectancy could increase the expected years of life lost due to some large causes.^c

(3) A third method for estimating the duration of time lost due to premature mortality is defined as *cohort expected years of life lost*:

$$\sum_{x=0}^{x=l} d_x e_x^c$$

where e^c is the estimated cohort life expectancy at each age. Clearly, cohort life expectancies must be estimated since we cannot know today the mortality experience a cohort will experience. However, the estimates based on past patterns of mortality decline are likely to be closer to the truth than period life expectancies. The difference in absolute terms between period and cohort expected years of life lost

^c Rothenberg R. Application of years of life lost to the elderly: demographic influences on a composite statistic. Presented at 46th Annual Scientific Meeting of the American Geriatrics Society, Boston, MA, 1989.

will be greatest for high mortality populations where substantial absolute mortality decline can be expected in the next decades. Despite the logical advantages of the cohort approach over the period approach, it still suffers from the criticism that it will not treat like events as like because cohort life expectancy will still differ from community to community. While inappropriate for measuring burden of disease, cohort life expectancy is the most attractive method of estimating the benefits of interventions for cost-effectiveness analysis.

(4) The advantages of the cohort expectation approach in the treatment of deaths at older ages and the egalitarian nature of the potential years of life lost methods can be combined. *Standard expected years of life lost* can be defined as:

$$x = \sum_{x=0}^l d_x e_x^*$$

where e^* is the expectation of life at each age based on some ideal standard. For DALYs, the standard has been chosen to match the highest national life expectancy observed; Japanese females have already achieved a period life expectancy at birth of close to 82 years. For a specific standard, the expectations are based on model life-table West Level 26 which has a life expectancy at birth for females of 82.5. Using a model life-table makes the standard expectations at each age easily available through publications and software distributed by the United Nations Population Division and eliminates some peculiarities of the Japanese age-specific mortality. Choosing one family of model life-tables over any other makes little or no difference to the results at such a low mortality level. With this indicator, deaths at all ages, even after age 82.5, contribute to the total estimated burden of disease while all deaths at the same age will contribute equally to the total estimated burden of disease.

Should the same standard expectation of life at each age be used for males as well as for females? One could argue on grounds of fostering equity that a male death at age 40 should count as the same duration of life lost as a female death at age 40. There appears, however, to be a biological difference in survival potential between males and females (28, 29). The average sex differences in life expectancy at birth in low mortality populations is 7.2 years (30). Not all this difference is biological; a large share is due to injury deaths among young males and higher levels of risk factors such as smoking. If we examine

high-income groups in low-mortality populations, the gap in life expectancy between males and females narrows considerably. Fig. 2 shows the differences in life expectancy by income groups in Canada (31). Where males are not exposed to high risks due to occupation, smoking, alcohol or injuries, the residual gap in life expectancy is narrowing dramatically. Projecting this forward, the ultimate gap in life expectancy at birth between the sexes is likely to approach 2 or 3 years. Independent estimates of the biological differences in survival potential have generated similar estimates (33). For the burden of disease study, we have chosen to use a life expectancy at birth of 80 for males and 82.5 for females from model life-table West.

In summary, the duration of time lost due to premature mortality can be measured by at least four different methods. Fig. 3 shows a comparison for a hypothetical population where period life expectancy at birth is 55. Four terms have been introduced to try and clarify the different methods of calculation, although this terminology is not yet in general usage. For the calculation of DALYs, we have chosen to use the standard expected years of life lost method with slight differences in the standard for males and females. To illustrate, the first two columns of Table 1 provide an abridged listing of the standard male and female expectancies used.

Social value of the time lived at different ages

In all societies social roles vary with age. The young, and often the elderly, depend on the rest of society for physical, emotional and financial support. Given different roles and changing levels of dependency with age, it may be appropriate to consider valuing the time lived at a particular age unequally. Higher

Fig. 2. Differences in life expectancy at birth for males and females, by income quintile, in urban Canada, 1986.

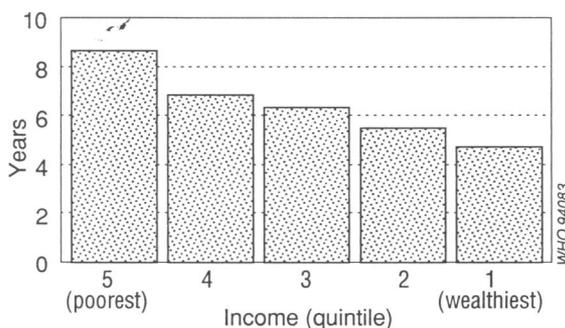
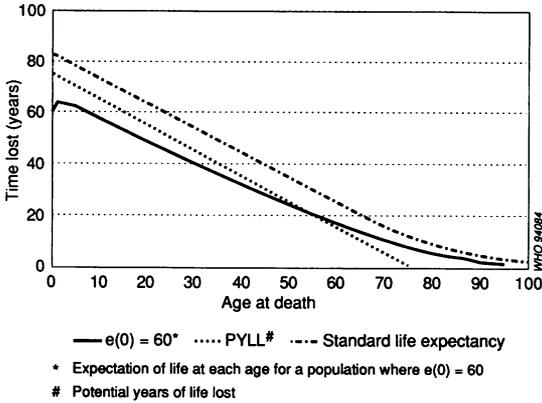


Fig. 3. Duration of time lost due to premature mortality at each age.



weights for a year of time at a particular age does not mean that the time lived at that age is *per se* more important to the individual, but that because of social roles the social value of that time may be greater. Fig. 4 illustrates graphically two contrasting approaches to the value of the time lived at different ages: uniform value or unequal age weights with more importance given to time in the middle age group.

Unequal weights can be justified within two different conceptual frameworks. First, the theory of human capital views individuals as a type of machine with costs of maintenance and expected output. The value of time at each age for this human production machine should be proportionate to productivity. Several of the original proponents of measuring the years of life lost proposed measures of working years of life lost (17–19). Piot & Sundaresan calculated the years of healthy living in the productive age groups as a health sector outcome measure.^d Several World Bank authors (33, 34) have used productivity weights in the calculation of years of life gained in cost-effectiveness studies. Barnum (34), in particular, suggests using average wage rates by age as the weighting factors. The logical extension of the human capital approach would be to weight time by other human attributes that correlate with productivity such as income, education, geographical location or even, in some economies, ethnicity. The obvious inequity is why no-one explicitly calls for this extension, even though it would only be

^d Piot M, Sundaresan TK. A linear programme decision model for tuberculosis control. Progress report on the first test-runs. Unpublished WHO document No. WHO/TB/Techn. Information/67.55, 1967.

Table 1: Standard life expectancy and DALYs lost due to premature death at each age^a

Age (years)	Life expectancy		Death DALYs	
	Females	Males	Females	Males
0	82.50	80.00	32.45	32.34
1	81.84	79.36	33.37	33.26
5	77.95	75.38	35.85	35.72
10	72.99	70.40	36.86	36.71
15	68.02	65.41	36.23	36.06
20	63.08	60.44	34.52	34.31
25	58.17	55.47	32.12	31.87
30	53.27	50.51	29.31	29.02
35	48.38	45.56	26.31	25.97
40	43.53	40.64	23.26	22.85
45	38.72	35.77	20.24	19.76
50	33.99	30.99	17.33	16.77
55	29.37	26.32	14.57	13.92
60	24.83	21.81	11.97	11.24
65	20.44	17.50	9.55	8.76
70	16.20	13.58	7.33	6.55
75	12.28	10.17	5.35	4.68
80	8.90	7.45	3.68	3.20

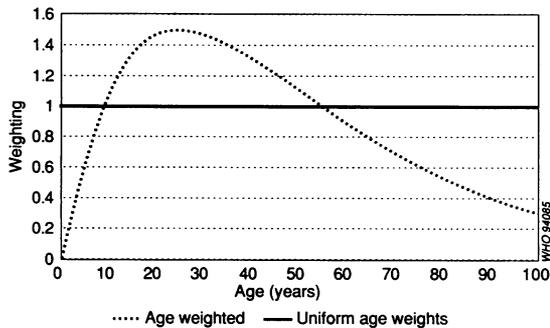
^a Life expectancy is calculated for the age at the beginning of the interval.

logically consistent. Because of this apparent inconsistency in the application of the human capital concept and because the human capital approach inadequately reflects human welfare, productivity weights are not used in the development of disability-adjusted life years.

Alternatively, we can view unequal age-weights as an attempt to capture different social roles at different ages. As all individuals can aspire to belong to each age group in his or her lifetime, Daniels argues that it is not unjust to discriminate by age (13). The concept of dependency and social role is broader than formal sector wage productivity and is not linked to total income levels. Unequal age-weights also has broad intuitive appeal. There has been little formal empirical work on measuring individual preferences for age-weights in the community; however, informal polling of tuberculosis programme managers by the author in an annual training course has revealed that everyone polled believes that the time lived in the middle age groups should be weighted as more important than the extremes. Not surprisingly there was no consensus on the precise weights to be used, only on the general functional form.

Having chosen to use unequal age-weights to capture different social roles through the life-cycle, how should specific weights be selected? With little empirical work on preferences for age-weights based on differing social roles as opposed to productivity, the only option was to use a modified Delphi method

Fig. 4. Age-weight function.



with a group of public health experts. One must also choose between establishing a set of discrete weights for each age or define a continuous mathematical function for the weights at each age. Discrete age-weights allow for great flexibility in the pattern chosen but require time-consuming iterative computations in their application.

For reasons of convenience, it is preferable to define a continuous age-weighting function. Functions of the form:

$$Cxe^{-\beta x}$$

where β is a constant having the general form shown in Fig. 4. This conforms to the basic age-weighting pattern desired. Only a narrow range of β provides reasonable age patterns, approximately between 0.03 and 0.05. Based on informal polling of the advisory board for this study, we chose a β of 0.04. As discussed by Murray et al. (3), the results are largely insensitive to the specific β chosen but are sensitive in certain qualitative ways to the difference between equal and unequal age-weights.

The constant C in the equation is chosen so that the introduction of unequal age-weights does not change the global estimated burden of disease from the total that would be estimated with uniform age-weights. Its value thus depends on the age and sex pattern of results of the global burden of disease in real populations detailed in Murray et al. (3). In another article on the global burden of disease published in this issue of the *Bulletin*, C equals 0.16243. If the age-weighting function were changed, for example by altering β , the constant would necessarily change as well.

Non-fatal health outcomes

Measuring non-fatal health outcomes in terms commensurate with time lost due to premature mortality

has been the subject of extensive research for three decades (35). Disease-specific measures such as attack rates date from the nineteenth century, but more general measures of non-fatal health outcomes became a major issue in the 1960s. A series of authors formulated models for composite indicators of mortality and morbidity (5, 6, 36–39).^e While each indicator had notable differences, they all defined a series of health states ranging from health to death, a series of weights reflecting the severity of these states and in some cases probabilities of movement from one state to another over time. Since these pioneering studies, intellectual efforts have evolved on three largely independent lines. Remarkably, for reasons of disciplinary focus, geographical and institutional locus, and types of health systems, the different strands of work on measuring non-fatal health outcomes have proceeded in relative isolation (40). The result is substantially different vocabulary, methods, and objectives and not surprisingly confusion. To provide the context for the disability-adjusted life year approach, the three domains of work will be briefly outlined.

Joint measures of non-fatal health outcomes and premature mortality were obviously of use in cost-effectiveness analyses of health projects (41–43). Consequently one line of development has been pursued by health economists interested in using the measures at the level of the individual or beneficiaries of a specific intervention. The now familiar term, the quality-adjusted life year (QALY), has become a standard tool in health programme evaluation in industrialized countries (43–45). In the work on QALYs, the focus has been on developing sophisticated methods for measuring individual preferences for time spent in different health states. For example, Nord (46) reviews five approaches developed to elicit utility weights for health states. Boyle & Torrance (47) have discussed a comprehensive system of health states, but this has yet to be applied. For most cost-effectiveness studies, health states have been defined *ad hoc* for a particular intervention such as coronary artery bypass grafting (48). The dimensions of physical, mental or social function within each state has received little attention in the QALY literature.

The second school of work has been the burgeoning field of health status indicators pursued largely in North America (see 49–51 for proceedings of three general conferences). Rather than the emphasis on choosing utility weights as in the estimation of QALYs field, the major thrust has been

^e See footnote d on page 435.

defining the precise dimensions of health status and practical survey instruments for measurement. Beginning initially with a narrow vision of disease, the measures have progressively incorporated variables related to physical function, mental function, and more recently social function (52). The term health-related quality of life has been used for this broader vision. The indicators themselves are weighted aggregates of a multitude of variables measuring specific functions or dimensions of physical, mental and social function. Research on new survey instruments has explored the differences between self-reported, proxy reported, independently observed, and objective functional tests. Reliability, various forms of validity (although rarely criterion validity), and feasibility of application are the basis for choice between indicators. The weights used in collapsing measurements of multiple variables into a single indicator have not been as much a topic for concern as in the QALY literature; frequently they are chosen on arbitrary grounds such as equal weighting.

The third cluster of work on measuring non-fatal health outcomes also dates from the early 1970s. A World Health Organization initiative in collaboration with the WHO Centre for the Classification of Diseases in Paris, and various nongovernmental organizations led to the publication of a draft classification of impairments, disabilities and handicaps in 1975^f and the *International classification of impairments, disabilities and handicaps* (ICIDH) in 1980 (53). The conceptual framework that emerged from this process is substantially different from the QALY or health status index approaches. In the manual of the ICIDH, a linear progression from disease to pathology to manifestation to impairment to disability to handicap is proposed. Impairment is defined at the level of the organ system, disability is the impact on the performance of the individual, and handicap is the overall consequences, which depend on the social environment. For example, a loss of a finger or an eye is an impairment. The consequent disability may be the loss of fine motor function or sight. Depending on the need in particular environments, the loss of function could lead to a handicap or disadvantage. The loss of fine motor function may be a greater handicap, in this terminology, for a concert violinist than for a bank-teller. Note the major difference between this approach which sees handicap as a completely different axis from disability and the health status field which adds social function

as one more in a long list of variables incorporated in a measure of health-related quality of life.

Both the World Health Organization and the United Nations Statistical Division have adopted the ICIDH. Currently, other countries are adopting the ICIDH as the basis for measuring disability and handicap. Le Réseau d'Espérance de Vie en Santé (REVES) is an independent network of academics and government agencies that are concerned with quantifying healthy life (54). In line with the ICIDH, REVES has proposed three indicators: impairment-free life expectancy, disability-free life expectancy, and handicap-free life expectancy (55). Reflecting the concerns of some associations of people with disabilities and handicaps, some members of REVES are actively opposed to the use of weights for different health states in calculating composite health indicators. *De facto*, in any of the health expectancies, weights of 0 and 1 are used somewhat arbitrarily. These health expectancies, such as disability-free life expectancy, weight all the time spent with a moderate or severe disability as equal to the time lost due to premature mortality, a weight of one. Mild disability is given a weight of zero. The threshold below which disability is weighted with zero is not clearly defined in this literature. Often a threshold is justified by pointing out that nearly everyone has some mild impairment, disability or handicap so that if milder outcomes were included, health expectancies would approach zero in all environments. If weights between zero and one were chosen as in DALYs, this would not occur.

Given the diverse approaches to measuring non-fatal health outcomes, many possible strategies could have been used for measuring the burden of disease. Prior to the Global Burden of Disease study, the only effort to evaluate the burden of disease due to disability and premature mortality by cause for an entire population was the Ghana Health Assessment Project (25). While that study was path-breaking, it did not publish the methods or rationale used for defining, measuring and weighting disability. Learning from past experience, we chose to deal more directly with disability measurement issues and to develop a practical approach that could be applied to over 100 diseases and their sequelae. Four key issues had to be addressed: defining disability classes, separating duration and severity, mapping diseases through to disabling sequelae, and choosing weights for different classes.

In the terminology of the *International classification of impairments, disabilities, and handicaps*, we have chosen to measure disability, not handicap. Handicap or disadvantage is an attractive concept because it focuses on the impact, given a particular social context of the individual. In some cases, simi-

^f Wood PHN. *Classification of impairments and handicaps*. Unpublished WHO document No. WHO/ICD9/REV.CONF/75.15, 1975.

lar disabilities may lead to a greater handicap for an already disadvantaged person than for the more fortunate. In many cases, however, allocating resources to avert handicap, as opposed to disability, could exacerbate inequalities. The manual of the ICIDH itself gives the following example: "Subnormality of intelligence is an impairment, but it may not lead to appreciable activity restriction; factors other than the impairment may determine the handicap because the disadvantage may be minimal if the individual lives in a remote rural community, whereas it could be severe in the child of university graduates living in a large city, of whom more might be expected." (53, p. 31).

Pursuing handicap could and probably would lead us to invest in avoiding mental retardation in the rich and well-educated but not in the poor. On even the most minimal principles of equity, this is unacceptable. The principle of treating like events as like requires using disability instead of handicap.

Having decided to measure disability, the challenge is to develop a way of capturing the multiple dimensions of human function in a simple scheme. Six disability classes have been defined between perfect health and death. Each class represents a greater loss of welfare or increased severity than the class before. Disabilities in the same class may restrict different abilities or functional capacities but their impact on the individual is considered to be similar. Table 2 provides a definition of each of the six classes. Limited ability has been arbitrarily defined as a 50% or more decrease in ability.

The classes are also defined operationally. A class is defined by the set of disabling sequelae included in that class. For those who work with individuals with a disability, looking at the set of disabling sequelae included in that class may make it much clearer what a Class 3 disability is. Operational validation forces us to ask: are the disabling sequelae in each class approximately similar and does each class represent a group of sequelae more severe than

the class before? As explained below, the final distribution of disabling sequelae by class was subject to the review of an independent group of experts.

The separation in the development of the disability-adjusted life year of duration of disability and severity must be emphasized. Severity of a disability could be a function of duration. A similar loss of function is argued to be worse per unit time if it is expected to be permanent than temporary. Man can endure suffering if the prospect of relief is near. In DALYs, severity or class weights are not a function of the time spent in each class but only of the class itself. This allows comparisons between the time lived with short- and long-term disabilities with the time lost due to premature mortality. A numerical example illustrates: 100 people each losing 0.1 of a DALY is a burden equal to 1 person losing 10 DALYs. We should note that experience in Oregon, with the application of cost-effectiveness to health resource allocation decisions, demonstrated that many individuals are against the separation of severity and duration (56). Through a series of town meetings, priorities for intervention based solely on cost-effectiveness criteria were modified. Analysis of these modifications demonstrated a concern for a larger quantum of benefits accruing to individuals as compared to the same number of QALYs accruing to more individuals (57). This concern would be captured better through a series of dispersion weights that adjusted for DALYs by the size of the health gain affecting the individual because part of this effect relates to the duration of time lost due to mortality rather than just the severity of the disability. Because experience is limited only to Oregon, we have not introduced dispersion weights into the analysis and have maintained the separation of disability duration and severity.

A major obstacle between public health studies on particular diseases and work on disability has been the absence of a probability map from disease

Table 2: Definitions of disability weighting

	Description	Weight
Class 1	Limited ability to perform at least one activity in one of the following areas: recreation, education, procreation or occupation.	0.096
Class 2	Limited ability to perform most activities in one of the following areas: recreation, education, procreation or occupation.	0.220
Class 3	Limited ability to perform activities in two or more of the following areas: recreation, education, procreation or occupation	0.400
Class 4	Limited ability to perform most activities in all of the following areas: recreation, education, procreation or occupation	0.600
Class 5	Needs assistance with instrumental activities of daily living such as meal preparation, shopping or housework.	0.810
Class 6	Needs assistance with activities of daily living such as eating, personal hygiene or toilet use.	0.920

through to impairments and disabilities. On paper arrows may be drawn from disease all the way to handicap, but even those who work on disability can rarely provide concrete information on the probability that someone with a particular disease will go on to suffer disabilities of differing severity. For the Global Burden of Disease study, such a mapping from disease through impairment to disability was developed. The details of the map and specific problems encountered are discussed in Murray & Lopez (2).

To compare the time lived in six disability classes with the time lost due to premature mortality, a weight for each class is required. At least five types of methods have been proposed to elicit preferences for health states from individuals (45, 46): rating scales, magnitude estimation, standard gamble, time trade-off, and person trade-off. In brief,

- (a) rating scales ask individuals to place different states on a scale from 0 to 100;
- (b) magnitude estimation asks direct questions about the relative value of the time spent in one state compared to another;
- (c) standard gambles ask individuals to choose between the certainty of living in a health state versus a chance of getting well at a probability p and dying at probability $1-p$;
- (d) time trade-offs elicit how much time an individual would exchange living in one state versus being healthy, such as 0.4 years of healthy life versus 1 year in a particular health state; and
- (e) in person trade-offs, individuals are asked to choose between curing a certain number of individuals in one disability class versus another number in a different class.

Time trade-off questions differ from the other methods because they confound questions of the utility of time spent in disability classes and the time preference rate discussed below. The last three methods all try to elicit the point at which the individual is indifferent between the two choices being offered. When the individual is indifferent the two outcomes are then equivalent and a weight is derived. Specific weights depend not only on the type of question used but on the group of respondents. Health care providers, patients, families of patients, and the general public may give different results to a specific question (46). The specific weights may depend on the question and respondent type but the ordinal ranking of health states is often less sensitive to the specific formulation.

Weights for the six classes have been chosen by a group of independent experts who had not been involved in the estimation of the incidence, duration or mortality of any disease, convened at the Centers

for Disease Control. They chose weights based on both the word definitions and the set of disabling sequelae in each class. *De facto*, they used a magnitude estimation method to choose a number between 0 and 1 for each of the six classes. Their votes were averaged to generate the final class weights provided in Table 2. How much do the specific weights matter? For classes 3 through 6, even if the weight is changed up or down by 0.1 it will have only a minor effect on the estimated burden of disease by cause. For Classes 1 and 2, however, the incidence times duration of disability is much higher and a change of weight from 0.05 to 0.1, for example, could have a significant effect on the results. Future work at the country level and at the global and regional level will benefit from a broader exercise to elicit weights for the six disability classes.

Time preference

At the simplest level, time preference is the economic concept that individuals prefer benefits now rather than in the future. The value of goods or services today is greater than in one or ten years. If offered the choice between 100 dollars from a completely reliable source today or 100 dollars in 1 year, most will prefer their money today. If offered 110 in one year versus 100 today, some may choose the 110 dollars. The bank interest rate on a savings account is the rate at which individuals are willing to forego consumption today for consumption in the future. The market rate of interest is the aggregate rate at which individuals in society as a whole discount future consumption. It is standard practice in economic appraisal of projects to use the discount rate to discount benefits in the future (58). The process of discounting future benefits converts them into present-value terms which can then be compared with project costs also discounted if they are spread over more than one year to determine cost-effectiveness.

However, despite the uniform use of discounting in cost-benefit and cost-effectiveness analysis, there is no consensus on the conceptual justification for discounting or on the appropriate discount rate (59, 60). Simplifying, there are two approaches to choosing the discount rate. One can use the social opportunity cost of capital as captured by the market rate of return on investment. Distortions of the market caused by corporate taxation and other interventions can complicate determining the social opportunity cost of capital. In practice, discount rates based on the social opportunity cost of capital are high (between 8% and 15%). The World Bank and the U.S. Congressional Budget Office have used a 10% discount rate for many years in project appraisal (61). Studies of long-term return on investments, however,

suggest a lower discount rate of 1–3%. The alternative concept is that society, like individuals, has a social time preference which should be used for discounting future benefits to society. This rate is thought to be lower than the market rate of interest (closer to 1–3%) (59).

Discounting years of health life or their equivalent has been used since Piot & Sundaresan in 1967 in many cost-effectiveness analyses.⁹ However, as health policy researchers have become more familiar with time preference, discounting health benefits has become highly controversial (62–75). While a detailed discussion of arguments for and against discounting is beyond the scope of this paper, a brief review of some arguments for social time preference may put discounting in a sharper perspective.

- First, individuals may have a pure time preference for no clear reason except myopia. Myopia is not a persuasive basis for social time preference. There is no reason to value welfare *per se* today more than welfare *per se* of the same individuals. Nor is there a reason for society to value the welfare *per se* of those alive today more than the welfare *per se* of those who are yet to be born.
- Second, if consumption is expected to grow in the future and there is decreasing marginal utility of consumption, then a marginal unit of consumption in the future will lead to less utility in the future and should be discounted. This logic for a positive discount rate may be reversed for health benefits. Disability-adjusted life years represent a measure of time gained or lost in the future. Time gives the potential to consume and derive utility; it is not equivalent to a fixed number of units of consumption. In fact, in the face of growing consumption a future DALY may yield more utility than a current DALY.
- Third, there is uncertainty correlating with time so that future outcomes need to be discounted to reflect the finite but non-zero risk that society will not exist at that time. Or in a less extreme form, it may be reasonable to expect an individual to incorporate his or her future risk of death each year into individual time preference, on average about 1% per year. For society, the equivalent risk of extinction will be much lower. Defining a plausible risk of social extinction is difficult, but attempts have been made to use certain probability distributions for estimates of uncertainty correlating with time.
- Fourth, Keeler & Cretin (75) have formalized a commonly appreciated problem known as the time paradox. If one argues that health benefits should not

be discounted or should be discounted at a rate lower than monetary costs, one will always choose to put off investing in a health project until the future. Benefits will be the same in present-value terms because they are not discounted. But the costs in present-value terms will be lower if the project is deferred to the future. Costs are lower because the budget could be invested and yield a positive return. A thousand dollars today will turn into \$1100 or \$1050 in a year. Only when costs and benefits are discounted at the same rate do we become indifferent to the time when a project is implemented. The time paradox depends on three critical assumptions: (a) the opportunity for health intervention will be the same in the future with similar costs and benefits, (b) it is politically feasible for society to receive more resources for health in the future in exchange for putting off current expenditure, and (c) the rate of return in other sectors or in financial markets is higher than in the health sector. If any of these do not hold, the time paradox is no longer relevant.

- Fifth, if health benefits are not discounted, then we may conclude that 100% of resources should be invested in any disease eradication plans with finite costs as this will eliminate infinite streams of DALYs which will outweigh all other health investments that do not result in eradication.

Recognizing that the debate on discounting health benefits will not be resolved in the near future, we have chosen a low positive rate of 3 percent for the calculation of DALYs. This is consistent with the long-term yield on investments. There is also a precedent in the World Bank Disease Control Priorities Study (27) that used a 3 percent rate. It avoids the difficulty of the time paradox and of overvaluing eradication programmes when no discount rate is used. Murray et al. (3) provide the sensitivity of the Global Burden of Disease results to varying the discount rate between zero and ten percent.

Introducing discounting into the computation of DALYs raises a number of technical questions. It complicates the choice between incidence and prevalence perspectives. With discounting, even with constant incidence rates, the number of DALYs computed using an incidence perspective for disability will be lower than using a prevalence perspective, because the stream of disability into the future will be discounted so that the last years in the stream will count much less than the first. Second, years of life lost due to premature mortality and years lived with a disability must be compared carefully. If we calculated the time lost from premature mortality which will occur in the future from current disease incidence, we get a different result than if we calculate the time lost due to premature mortality occurring

⁹ See footnote d on page 435.

this year. Even if death rates were constant over time, discounting would introduce a difference. The only practical solution, however, is to assess the time lived with a disability by using current incidence and the time lost due to premature mortality by using current death rates.

Third, we can calculate the discounted stream of lost life due to premature mortality at age a by discounting the number of years as estimated from the standard.

$$\frac{1}{r} - \frac{e^{-rL}}{r}$$

where r is the discount rate and L is the standard expectation of life at age a . An expectation of life is the average number of years expected, but expected deaths will be distributed over many ages. Because discounting is a nonlinear function, the average of a discounted distribution is not equal to the discounted value of the average of a distribution. A more precise estimate of the discounted life expectation would take into account the distribution of the ages of death. Discounting the survivorship function, however, yields results that are only marginally different. The discounted duration of time lost due to premature death at each age, calculated using the survivorship function method, for females ranges from 0.8% to 2.3% (from 1% to 3% for males) less than the direct method. Because of the minor differences and the tremendous advantages of defining a single formula for calculating DALYs, the direct method for discounting has been chosen.

DALY formula

In summary, the disability-adjusted life year is an indicator of the time lived with a disability and the time lost due to premature mortality. The duration of time lost due to premature mortality is calculated using standard expected years of life lost where model life-table West with an expectation of life at birth of 82.5 for females and 80 for males has been used. Time lived at different ages has been valued using an exponential function of the form $Cxe^{-\beta x}$. Streams of time have been discounted at 3%. A continuous discounting function of the form $e^{-r(x-a)}$

has been used where r is the discount rate and a is the age of onset.^h Disability is divided into six classes, with each class having a severity weight between 0 and 1. Time lived in each class is multiplied by the disability weight to make it comparable with the years lost due to premature mortality.

A general formula for the number of DALYs lost by one individual can be developed:

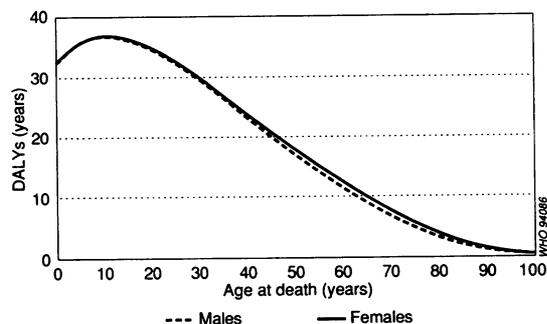
$$\int_{x=a}^{x=a+L} DCxe^{-\beta x} e^{-r(x-a)} dx$$

The solution of the definite integral from the age of onset a to $a+L$ where L is the duration of disability or time lost due to premature mortality gives us the DALY formula for an individual:

$$-\left[\frac{DCe^{-\beta a}}{(\beta+r)^2} [e^{-(\beta+r)L} (1+(\beta+r)(L+a)) - (1+(\beta+r)a)] \right]$$

where D is the disability weight (or 1 for premature mortality), r is the discount rate, C is the age-weighting correction constant, β is the parameter from the age-weighting function, a is the age of onset, and L is the duration of disability or time lost due to premature mortality. This formula can be conveniently written in a spreadsheet cell to facilitate calculation of DALYs. In the specific form used for calculating DALYs, r equals 0.03, β equals 0.04, and C equals 0.16243. The general form of the DALY formula facilitates the sensitivity testing presented in Murray et al. (3). Fig. 5 presents the number of DALYs lost due to a death at each age for a male and a female. This pattern is the aggregate results of the duration of time lost due to premature mortality, age-weighting and discounting but the figure does not reflect any disability.

Fig. 5. DALYs lost due to death at each age.



^h Note that in a continuous discount function r is not precisely the same as r in the discrete form. The formula for the discrete form is simply $1/(1+r)^t$. If the discount rate in the discrete formula is r , then the equivalent result is achieved with a continuous discount rate of $\ln(1+r)$.

Conclusion

Disability-adjusted life years as an indicator is consistent with a long line of work on composite indicators of non-fatal health outcomes and premature mortality. While DALYs must be viewed as only one more step in a long development process, there are several aspects about them that are worth noting when comparing DALYs by cause, age, sex, and region with other indicators.

- The particular set of value choices — the duration of life lost, the value of life lived at different ages, comparison of the time lived with a disability with the time lost due to mortality, and the time preference — all differ from past indicators. They have been selected in such a way that the indicator is comparable across a wide range of environments. We also believe that value choices reflect a broad consensus among those practising international public health. However, as the sensitivity analysis shows (3), many of the conclusions of the Global Burden of Disease study are unaffected by changes in those parameters.

- Apart from the specific value choices, the major difference between DALYs and more widely available measures such as potential years of life lost is, of course, the inclusion of the time lived with a disability. As demonstrated elsewhere (3), 34% of the global burden of disease is due to disability; some causes such as neuropsychiatric diseases appear as major problems using DALYs but not using potential years of life lost.

- Estimates of the burden of disease denominated in DALYs can easily be used in conjunction with the literature on cost-effectiveness of health interventions. For example, the largest compendium of international health interventions has reported results in terms of cost per DALY (27). This facilitates using estimates of the burden of disease in determining health resource allocations.

- The more original aspect of DALYs is not their design but the successful application of the indicator to measure the burden of disease for over 100 diseases in eight regions for five age groups among males and females. While details such as the distribution of disabling sequelae by class are bound to be changed in the future as more information is obtained, it is already established as a feasible alternative for assessing the burden of disability and premature mortality.

Acknowledgements

This work would not have been possible without the tremendous efforts of Caroline Cook. Extensive comments

from P. Musgrove, M. Reich and A. Lopez were very helpful. J.-L. Bobadilla, D. Jamison, J. Zeitlin, W. Whang, J. Kim, S. Anand, J. Koplan, K. Hill, J.-M. Robine, R. Wilkins and R. Rannan-Eliya provided constructive comments and suggestions for improvement.

Résumé

Mesure quantitative du poids de la morbidité: base de calcul des années de vie ajustées sur l'incapacité

La prise de décision concernant la ventilation des ressources pour la santé exige la connaissance d'un indicateur du poids de la morbidité. Il faut en outre disposer d'un indicateur unique car, en fin de compte, c'est l'ensemble des événements de santé qui sont rapportés aux dépenses de santé. Pour élaborer un indicateur du poids de la morbidité, quatre principes généraux ont été utilisés et articulés. Tout d'abord, dans la mesure du possible, tout événement qui représente une perte de santé doit être inclus dans un indicateur de l'état de santé. Deuxièmement, les caractéristiques du sujet qui présente l'événement de santé dont on tiendra compte dans le calcul du poids de la morbidité correspondant, seront limitées à l'âge et au sexe. Troisièmement, des événements identiques seront considérés de manière identique, à savoir que le décès d'une femme de 40 ans au Burundi est censé avoir la même valeur dans le poids de la morbidité mondiale que le décès d'une femme de 40 ans à Boston (Etats-Unis d'Amérique). Quatrièmement, le temps est utilisé comme unité de mesure commune du poids dû au décès prématuré et à l'incapacité. Les années de vie ajustées sur l'incapacité (DALY: *Disability Adjusted Life Years*) sont calculées en faisant intervenir la notion d'incidence et de durée et non celle de prévalence.

Quatre choix sociaux, ou préférences, doivent être inclus dans tout indicateur du poids de la morbidité. On envisage tout d'abord les années perdues par suite d'un décès prématuré. Depuis l'introduction de ce concept en 1947, quatre méthodes sont utilisées: les années potentielles de vie perdues, les années de vie perdues attendues pour la période, les années de vie perdues attendues pour la cohorte, et les années de vie perdues attendues standardisées. De manière à traiter comme il convient les décès dans la population de 60 ans et plus, et à traiter de manière égale tous les décès au même âge dans toutes les populations, nous avons utilisé la méthode des années de vie perdues attendues standardisées.

C'est la table de mortalité modèle Ouest, avec une espérance de vie à la naissance de 82,5 ans pour les femmes et de 80 ans pour les hommes qui a été choisie comme norme pour les femmes.

Le deuxième choix social examiné est la valeur du temps vécu aux différents âges. Toutes les durées pourraient être considérées comme égales. Cependant, on peut tenir compte du fait que les jeunes et les personnes âgées sont dépendants des adultes d'âge intermédiaire. Les différences de rôle social ont été explicitement introduites dans le calcul des DALY en utilisant une fonction exponentielle de forme $x e^{-bx}$ pour pondérer l'âge. S'appuyant sur le consensus du groupe consultatif réuni pour l'étude, une forme spécifique a été choisie pour b .

Troisièmement, le nombre d'années passées avec une incapacité de gravité plus ou moins grande doit être comparé au nombre d'années perdues par décès prématuré. Les publications sont nombreuses sur la mesure des événements de santé non fatals et peuvent être regroupées arbitrairement en trois catégories: celles qui s'apparentent à l'économie de la santé traditionnelle et s'attachent plus particulièrement aux QALY (*Quality Adjustments of Life Years*: années de vie sauvées ajustées sur la qualité), celles qui s'intéressent à la qualité de vie liée à la santé et celles qui utilisent la CIH (*Classification internationale des handicaps: déficiences, incapacités et désavantages*). Pour pouvoir mesurer comparativement les années vécues avec une incapacité et la mortalité, six classes d'incapacité ont été définies, de l'état de santé parfait au décès. Une définition descriptive est formulée pour chacune des classes. Ce qui est encore plus important est que chacune est en outre définie opérationnellement par un ensemble de séquelles incapacitantes consécutives à la maladie ou au traumatisme inclus dans chaque classe. Le coefficient de pondération va de 0 à 1, et a été choisi pour chacune des classes par un groupe d'experts indépendant n'ayant pas connaissance des détails de l'étude.

Quatrièmement, il est tenu compte de la notion économique d'actualisation de préférence temporelle. Qu'il s'agisse des individus ou de la société, tous tendent à préférer des avantages immédiats à des avantages différés. Il est tenu compte de cette préférence temporelle dans le calcul, en appliquant un taux d'actualisation aux avantages différés. L'utilisation d'une préférence temporelle positive dans l'analyse d'une suite de bénéfices pour la santé comme les années de vie sauvées est très contestée. Nous conformant à

plusieurs précédents bien établis, nous avons utilisé un taux d'actualisation de 3%. La formule de calcul des DALY est ensuite indiquée, accompagnée de certaines réflexions sur les avantages et les inconvénients de cet indicateur comparé aux autres indicateurs de l'état de santé.

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